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Request for grant of a patent

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1.	Your reference	42713/IML
2.	Patent application number *(The Patent Office will fill in this part)*	**0100093.4** 04JAN01 E595231-1 D01631 F01/7700 0.00-0100093.4
3.	Full name, address and postcode of the or of each applicant *(underline all surnames)*	VTECH COMMUNICATIONS, LTD. 23/F., Tai Ping Industrial Centre Block 1, 57 Ting Kok Road Tai Po, N.T., Hong Kong
	Patents ADP number *(if you know it)*	07435001001
	If the applicant is a corporate body, give the country/state of incorporation	Hong Kong
4.	Title of the invention	Adapative Frequency Hopping Strategy
5.	Full name, address and postcode in the United Kingdom to which all correspondence relating to this form and translation should be sent	Reddie & Grose 16 Theobalds Road LONDON WC1X 8PL
	Patents ADP number *(if you know it)*	91001 ✓

		Country	Priority application *(If you know it)*	Date of filing *(day/month/year)*
6.	If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number			

		Number of earlier application	Date of filing *(day/month/year)*
7.	If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application		

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*
a) any applicant named in part 3 is not an inventor, or
b) there is an inventor who is not named as an applicant, or
c) any named applicant is a corporate body.
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YES

9. E... the number of sheets for any of the following items you are filing with this form. Do not count copies of the same document.

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Continuation sheets of this form	
Description	9
Claim *(s)*	0
Abstract	0
Drawing *(s)*	1 + 1

10. If you are also filing any of the following, state how many against each item.

Priority documents	
Translations of priority documents	
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	
Request for preliminary examination and search *(Patents Form 9/77)*	
Request for substantive examination *(Patents Form 10/77)*	
Any other documents *(please specify)*	

11. I/We request the grant of a patent on the basis of this application.

Signature

Date
3 January 2001

12. Name and daytime telephone number of person to contact in the United Kingdom

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b) *Write your answers in capital letters using black ink or you may type them.*
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TITLE OF THE INVENTION

Adaptive Frequency Hopping Strategy

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates in general to wireless digital communications. In particular, the invention relates to a frequency hopping strategy for use in frequency hopping spread spectrum communications.

2. Background Art

Devices incorporating wireless communications techniques are becoming increasingly prevalent in modern society. An inevitable result of this trend is that frequency spectrums are becoming more crowded and prone to interference. At the same time, consumers are becoming increasingly concerned about the privacy and security of communications. Consequently, systems engineers designing a variety of wireless communications systems, including cellular and cordless telephones, are increasingly turning to digital spread spectrum signaling methods to achieve better voice quality, greater security, and more efficient bandwidth utilization than can be achieved with conventional signaling methods, such as amplitude or frequency modulation without bandwidth spreading.

One popular spread spectrum signaling technique is frequency-hopping spread spectrum ("FHSS"). A FHSS transceiver operates by rapidly changing its tuned carrier frequency in a known pattern, called the hop sequence or hop pattern. By using different hop sequences, multiple users can communicate simultaneously over differing communications channels all within a common frequency bandwidth. FHSS offers better voice quality than other solutions in noisy environments because

a short segment of voice data transmitted on a "bad" channel is simply muted. When the number of bad channels in the hop sequence is relatively low, the resultant degradation in voice quality is not noticeable to the user.

Another aspect of FHSS systems which is particularly advantageous is the ability to circumvent interference at a particular frequency by dynamically changing the channels in the hop sequence, substituting a new frequency channel for a detected/identified "bad" channel. Numerous methods of monitoring channel performance and determining when a channel should be removed from the hop sequence are known in the art.

However, typical prior art systems simply randomize the entire pool of frequency channels, before selecting an initial subset of channels on which communication is to occur, and leaving a random pool of reserve channels ready for substitution. Thus, there is a significant probability that adjacent channels in the hop sequence will be similar in frequency. When this occurs, a broadband source of interference could block several consecutive channels in the hop sequence, thereby inhibiting data communications required for implementation of dynamic channel allocation techniques.

Moreover, when a substitution takes place, many systems select a random channel from amongst the reserve. Therefore, many times the new channel that is substituted into the active hop sequence will likewise suffer from interference, or be otherwise unsatisfactory, such that yet another substitution is promptly required.

Therefore, in accordance with an aspect of the invention, an improved technique for frequency hopping channel selection and substitution is presented. The issue is involved with single or multiple handset, frequency hopping radio systems. For simplicity, the discussion in this proposal will be based on a single

handset system, but the concepts described will equally apply to a multiple handset system. The discussion is also based on the use of the proposal in a cordless telephone system, but again the application of the proposal is not limited to such a system.

DESCRIPTION OF THE INVENTION

While this invention is susceptible to embodiment in many different forms, there are shown in the drawings and will be described in detail herein specific embodiments. The present disclosure is to be considered as an exemplification of the principle of the invention intended merely to explain and illustrate the invention, and is not intended to limit the invention in any way to embodiments illustrated.

The illustrated embodiment of the frequency hopping strategy is based on the integration of the three aspects: selection of initial frequencies, assessment of frequency quality, and substitution of frequencies.

Initial Frequency Selection

The purpose of the frequency selection process is summarised as follows:

1. Produce a list of working frequencies common to a BS & HS pair with which they can acquire initial synchronisation and perform subsequent communications.
2. Randomisation of the working frequencies to reduce the perception of interference and to comply with FCC regulations.
3. Minimises interference between adjacent systems (due to frequency collisions) by generating hop sequences unique to each BS/HS pair.

4. Greatly reduce the effect of wide-band interference through the use of alternate high/low frequency pairs for the working frequencies. This also enhances the properties of the 'Noise Buster' technology.
5. Fast, efficient, time-predictable implementation requiring minimal MIPS, ROM & RAM. For example, permanent RAM requirement is limited to the size of the frequency table, and less than 10 words of (re-useable) stack space.
6. Provide a pool of spare frequencies to implement adaptive interference control.

Frequency selection proceeds as follows: all the available 102 frequencies are arranged in a table in order of ascending frequency. The lower 51 (102/2) frequencies and the upper 51 frequencies are now permuted independently with the aid of a fast & effective pseudo-random number generator. This generator is a 32 bit linear feedback shift register (LFSR) using Galoise feedback. It is seeded by a 32-bit binary number which is unique to the BS & HS pair (the Base Station ID), to produce frequency permutations unique to the BS/HS pair.

The 2 half-tables are now combined by swapping alternate high/low frequency pairs from the 2 halves. A subset of working frequencies is now chosen by selecting the first 'N' frequencies at the start of the table. The remainder is set aside for assessment as spare frequencies. A typical result of the initial frequency selection process is depicted graphically in the drawing of Figure 1.

The working frequencies are used to achieve initial synchronisation between BS & HS. The working frequency set then slowly evolves with use to avoid bad frequencies, as working frequencies on which interference is detected are swapped out for spare frequencies.

Frequency Assessment

Frequency quality monitoring is performed to identify bad frequencies so that they can be avoided. It may be desirable to perform frequency assessment at the BS end of the link since this prolongs the battery life in the HS. Frequency assessment is carried out in 2 distinct stages:

1. Identifying Good Alternative Frequencies

The illustrated cordless telephone spends much of its time 'On Hook' with the HS in a low-power idle state, when there is very little traffic between BS & HS. While the HS is idle the BS is monitoring the noise level on each of the spare (non-working) frequencies.

All the spare frequencies are held in a table and are sorted in order of descending quality so that the best frequencies can be readily identified when needed later by the frequency substitution process. This system avoids using scarce RAM to log quality factor information for each individual frequency; only a single temporary location (re-usable stack) is required to perform the substitution. It also provides quick sequential access to the best frequencies first, without needing any further computation.

In this context, a good frequency is defined as one associated with a low noise level, as measured by the RSSI circuitry.

2. Identifying Bad Working Frequencies

The RSSI strategy doesn't guarantee to identify ideal working frequency since, in practice, other factors can influence the noise reading e.g. strong adjacent channel interference, varying sensitivity across the band, noise within the BS circuitry, etc. Hence a different strategy can be employed for identifying good and

bad working frequencies based on measuring actual propagation. This strategy has the added advantage that it can be thoroughly tested using a base-band hopping simulator before being validated on a 'live' RF link with all the attendant problems involved.

A frequency is deemed to be bad if it consistently fails to properly propagate a radio signal from the HS to the BS i.e. transmitted data is not received or is corrupted.

Monitoring is conducted in the 'Off Hook' condition once a voice link has been established. In the illustrated embodiment, a frequency is deemed to be bad, and hence in need of substitution, if it fails to propagate on 2 successive occasions. This ensures that transient noise is ignored which reduces needless substitution which could otherwise cause congestion on the very limited control channel bandwidth available between BS & HS.

Since there are only 102 possible hopping frequencies, all hop number can be encoded into 7 bits of RAM. This allows the 8th bit of each byte to be used as a 'noise flag' so no additional RAM is required to implement a very effective noise filter.

Frequency Substitution

The aim of the frequency substitution protocol is simply to optimise the quality of the link by avoiding bad frequencies. The protocol described here ensures that both ends of the communications link maintain a common hop-set while requiring only a modest bandwidth between BS & HS.

In the Off Hook condition the BS monitors the link on a hop-by-hop basis. The traffic quality of each hop is measured during the hop and assessed shortly

afterwards, early in the next hop. Once the frequency is deemed to be bad (as described above) then the BS performs the following action:

1. The BS swaps the bad frequency with the best available replacement from the list of good alternative frequencies.
2. It informs the HS to perform this substitution; this information is sent in a data packet on the communications link.

At the beginning of the frequency substitution process the link is, arguably, in its worst state in terms of communications quality and the substitution information may not get through. This is potentially catastrophic since only one end (the BS) would be using the new frequency on the next round i.e. a bad link can be made much worse. The following techniques can be employed to prevent this situation from arising: automatic re-send, automatic retry, automatic repair, and congestion control.

Automatic Re-send

In some embodiments, the communications link lacks the capacity to support a reliable (SEND/ACK/TIMEOUT) frequency replacement protocol since a linear increase in blocked hops soon results in an exponential increase in traffic. Hence, in the illustrated embodiment, the substitution packet is simply transmitted twice; by sending the repeats on different hops they are transmitted on a high/low pair of frequencies which greatly reduces the chance of corruption due to wide-band noise. Sending the packets immediately after the blocked hop is detected guarantees that neither packet will be transmitted on that blocked hop (which is now different at BS & HS until the data arrives at the HS).

A potential weakness of this system is that each blocked hop requires 2 packets to be transmitted, and this occupies valuable bandwidth. However, the 'substitute' command only requires 2 bytes of the 4 bytes available within each packet. Hence 2 'substitute' commands are packed into each packet as and when required. This means that the communications efficiency tends to increase with increased traffic.

It should be noted that, while the BS performs a frequency 'swap', the HS performs a 'substitute'. This is because the BS only performs this action once whereas the HS can act on one or both of the re-sends and would otherwise perform a swap followed by an un-swap.

Automatic Retry

There is still a possibility that both the 'substitute' commands fail to get through or that the frequency becomes blocked for some other reason e.g. the new frequency is itself blocked. This would become apparent when the frequency is next monitored. The noise flag would now be set and a further substitution occurs on the next round. The scheme is hence inherently resilient.

Automatic Repair

From the previous section it can seen that if the 'substitute' command fails to get through then another one of the spare good frequencies is eventually consumed (wasted). In order to conserve good frequencies an additional feature is activated when the noise flag is set. At this point a special 'repair' command is sent which simply communicates the current setting which has the effect of re-synchronising the working frequency sets in the BS & HS. This is akin to automatic puncture repair.

Congestion Control

Congestion control is applied to both the 'substitute' and to the 'repair' commands. Performing too many substitutions (e.g. when the voice link is just being established) can conceivably possibly degrade an already bad link and the attendant congestion could block all other data traffic. For this reason a 1 byte of RAM is used as a traffic counter. This is also used to give priority to sending the 'substitute' command in preference to the 'repair' command.

Congestion control is essential when no good working set of frequencies can be found. However, under these circumstances the attendant voice link is unlikely to be useable. A count of blocked hops is maintained and made available to the link management software which could then decide to shut down the link gracefully. This would typically happen as the HS wanders out of radio range.

The foregoing description and drawings merely explain and illustrate the invention and the invention is not limited thereto, inasmuch as those skilled in the art, having the present disclosure before them will be able to make modifications and variations therein without departing from the scope of the invention.

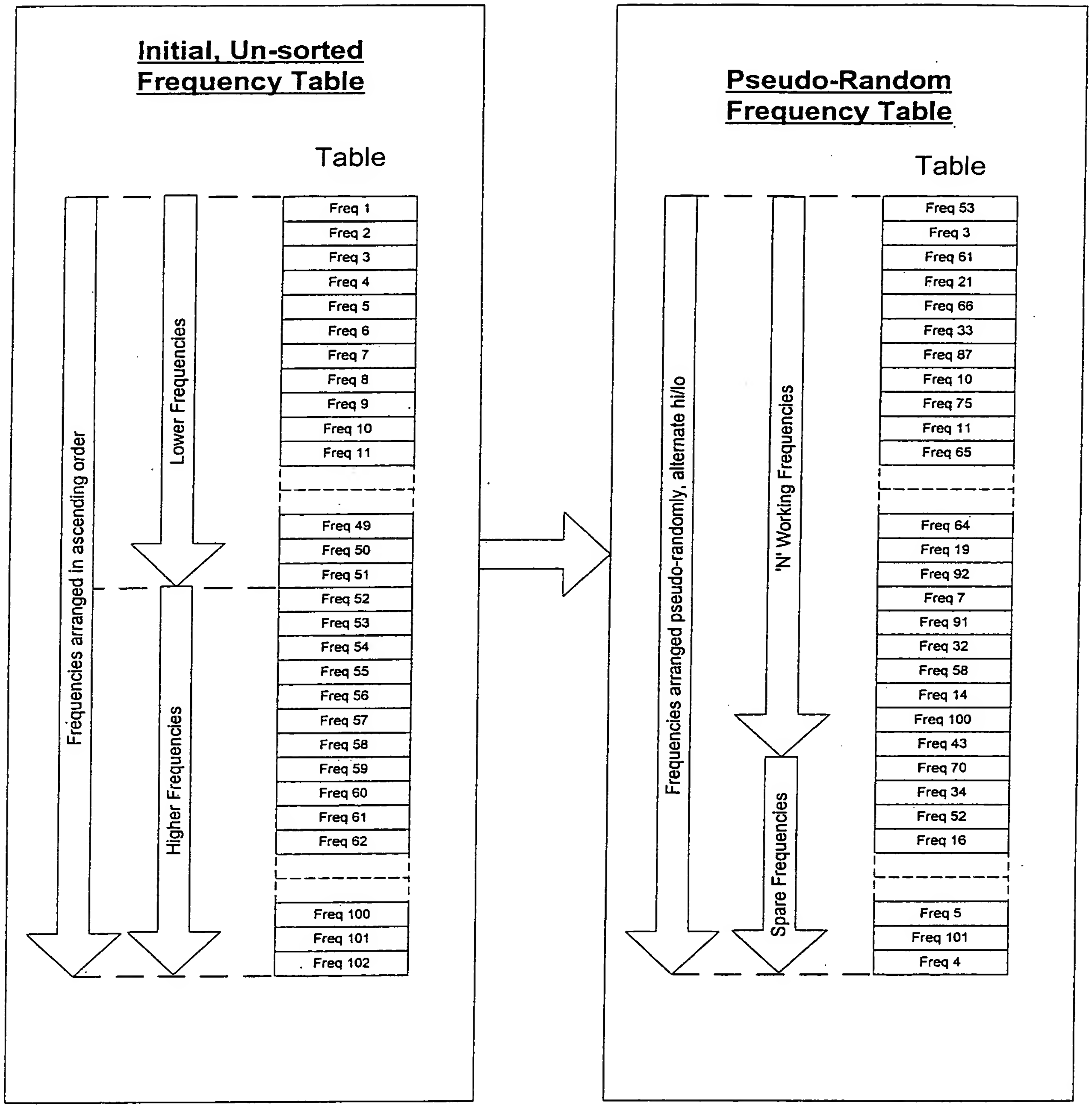
Initial, Un-sorted Frequency Table
Table
Frequencies arranged in ascending order
Lower Frequencies
Higher Frequencies
Freq 1
Freq 2
Freq 3
Freq 4
Freq 5
Freq 6
Freq 7
Freq 8
Freq 9
Freq 10
Freq 11
Freq 49
Freq 50
Freq 51
Freq 52
Freq 53
Freq 54
Freq 55
Freq 56
Freq 57
Freq 58
Freq 59
Freq 60
Freq 61
Freq 62
Freq 100
Freq 101
Freq 102
Pseudo-Random Frequency Table
Table
Frequencies arranged pseudo-randomly, alternate hi/lo
'N' Working Frequencies
Spare Frequencies
Freq 53
Freq 3
Freq 61
Freq 21
Freq 66
Freq 33
Freq 87
Freq 10
Freq 75
Freq 11
Freq 65
Freq 64
Freq 19
Freq 92
Freq 7
Freq 91
Freq 32
Freq 58
Freq 14
Freq 100
Freq 43
Freq 70
Freq 34
Freq 52
Freq 16
Freq 5
Freq 101
Freq 4

Figure 1